Coal Strip-Mined Land in Indiana

By RICHARD L. POWELL

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY SPECIAL REPORT 6

PRINTED BY AUTHORITY OF THE STATE OF INDIANA
BLOOMINGTON, INDIANA: 1972

STATE OF INDIANA
Edgar D. Whitcomb, *Governor*
DEPARTMENT OF NATURAL RESOURCES
John R. Lloyd, *Director*
GEOLOGICAL SURVEY
John B. Patton, *State Geologist*

For sale by Geological Survey, Bloomington, Ind. 47401
Price $1.00

Contents

Illustrations

Illustrations

Tables

Coal Strip-Mined Land in Indiana

By RICHARD L. POWELL

Abstract

Almost 100,000 acres of land has been disturbed by strip mining in southwestern Indiana within the past 50 years. Pike, Warrick, and Clay Counties contain about two-thirds of the strip-mined land. Strip-mined land amounts to about .4 percent of the total land of Indiana and about 2 percent of the total land area of the 21 counties in southwestern Indiana that contain strip mines. Coal has been removed from only about 75,000 acres, and thus spoil dumped on unmined land amounts to about 27 percent of the total disturbed area. The Springfield Coal Member (V) accounts for about 50 percent of the coal produced, of which about 80 percent has been mined in Pike and Warrick Counties. Strip mining takes essentially all coal from the area uncovered, but deep mining leaves about 50 percent of the coal in the mined area as roof support.

Introduction

DEFINITION OF STRIP MINING

Strip mining is the term commonly used in southwestern Indiana in describing the surface-mining method for coal. It differs from other methods of mining in Indiana in that the material sought (coal) is in most places thin in relation to the thicker bedrock strata (mostly sandstone and shale) and unconsolidated drift and soil, called overburden, that overlie it. Underground coal-mining methods do not handle or move the overburden, and surface mining for other mineral commodities, such as clay, shale, or gravel, is not usually done where thick overburden is present. Mining of other mineral commodities is generally regarded as open-pit mining. Strip mining for coal is commonly done by excavating the overburden from above the coal with a large shovel or dragline, although smaller equipment and bulldozers are used for small-scale operations. The first cut is made by depositing the overburden on the original land surface, but the overburden from each subsequent adjacent cut is dumped into the last open cut. The coal is removed from each cut with small shovels after the overburden has been removed and before the overburden from the next adjacent cut is dumped. The cut-and-fill operation proceeds in strips, much like furrows in a plowed field. The last cut is usually left unfilled, except for covering the unmined coal with a thin cover of dirt, and may contain a strip mine lake or pond if it is a suitable watertight catchment area. The overburden removed in the mining process is usually left in ridges that are commonly called spoil banks but that have recently been called cast overburden.

REASON FOR STUDY

The aftermath of strip mining has become a subject of local and national concern. This study was undertaken to determine the amount and distribution of land in Indiana that has been strip-mined for coal. This information should lead to additional studies on land reclamation and to future planning by local, state, and federal agencies.

METHOD OF OBTAINING DATA

The outlines of strip mines were obtained from the most reliable source: original mine maps, aerial photographs, or 7½-minute topographic maps. These outlines were plotted on topographic maps to delimit strip-mined land in two categories: those areas where coal had been mined and adjacent areas where coal had not been removed but where the surface had been disturbed by cuts or fills. In general, it was obvious that mine maps prepared by land surveyors did not depict the outline of the pit nor the additional spoil banks as accurately as aerial photographs, and thus where possible the outline was taken from aerial photographs. The mine maps were prepared immediately or soon after the land was stripped, but the aerial photographs were taken several to many years later. In some places photographs taken many years after the land was stripped show that the original spoil had mass-wasted and spread out over more land than is shown on the mine maps or earlier aerial photographs. Recent mine maps show the mine workings more accurately than do those prepared earlier. Some modern strip mine maps are prepared from aerial photographs and are a more accurate and reliable form of mining record.

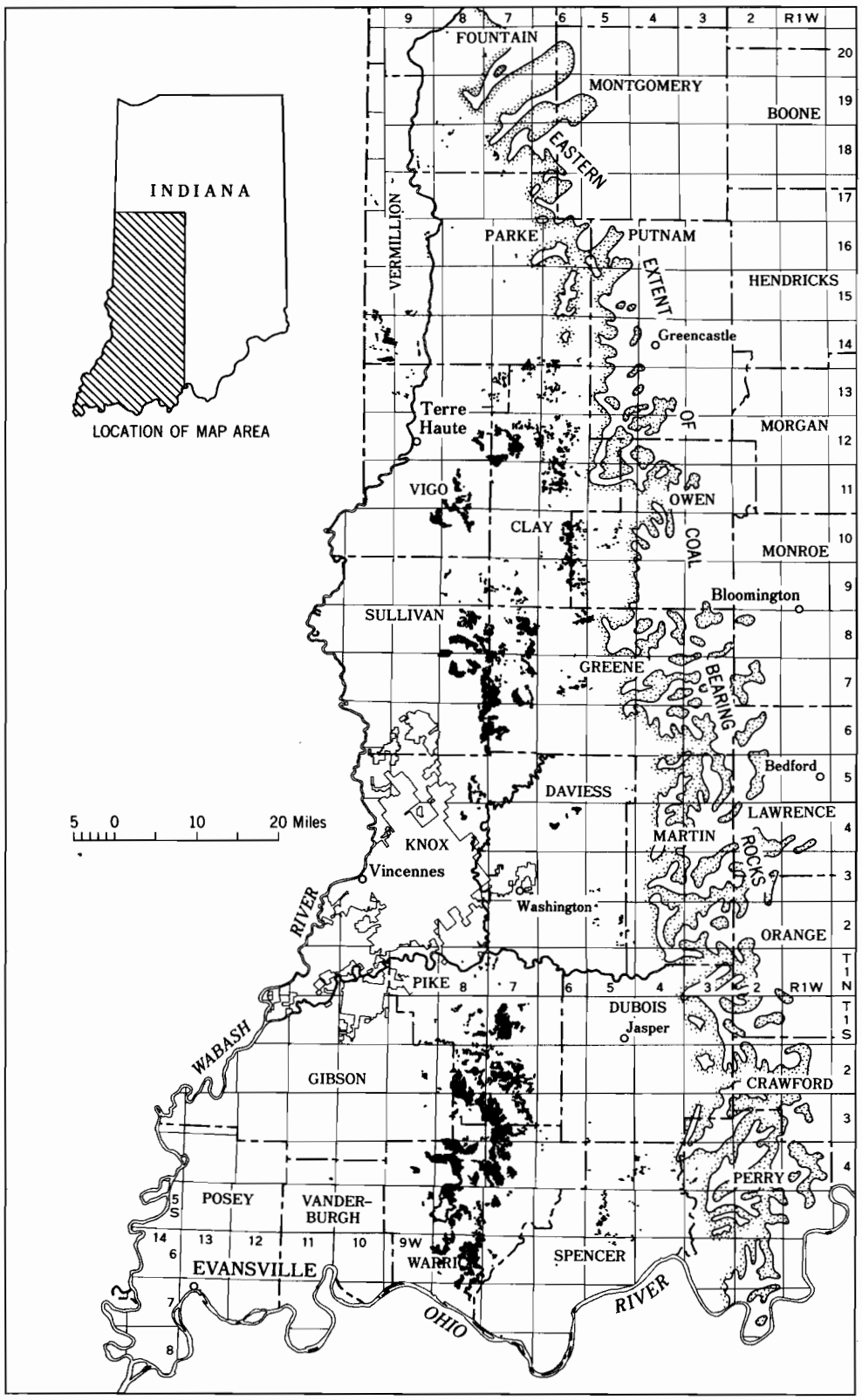

Figure 1. Map of southwestern Indiana showing distribution of strip-mined land to June 1972. Modified from Powell, 1972.

The acreage of land where coal has been removed and the acreage of additional disturbed areas were determined by following the strip mine outlines on the 1:24,000 topographic maps with a Bruning 80-150 compensating polar planimeter. Marvin Iverson, geological assistant in the Coal Section of the Indiana Geological Survey, made most of the planimeter measurements. A series of sheets was prepared at a scale of 1:63,360 for tabulating data by county and preparing a small-scale map showing the distribution of strip-mined land in Indiana (fig. 1).[1]

Geology

LOCATION OF STRIP-MINED LANDS

Strip mining for coal in Indiana is restricted to an area of 6,500 square miles in the southwestern part of the state where commercial coalbeds of Pennsylvanian age crop out along the east side of the Eastern Region of the Interior Province (fig. 2). The numerous coalbeds dip generally southwestward into the Illinois Basin at an average rate of about 25 feet per mile. A few large structural flexures and numerous small structures interrupt what otherwise would be a gentle monoclinal dip on the flank of the basin.

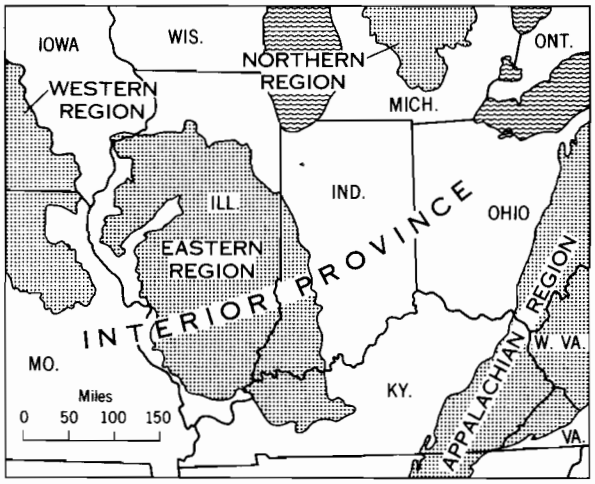

Figure 2. Map of part of the east-central United States showing coal regions in relation to Indiana. From Trumbull, 1960.

PHYSIOGRAPHY

The Indiana portion of the Eastern Region is drained entirely by the Wabash and Ohio Rivers and their tributaries. These streams and the two forks of White River occupy broad valleys that are in part deeply filled with glacio-fluviatile sediments. Very little strip mining has been accomplished in the valleys because of the water problems encountered within the aquifers in the unconsolidated sediments.

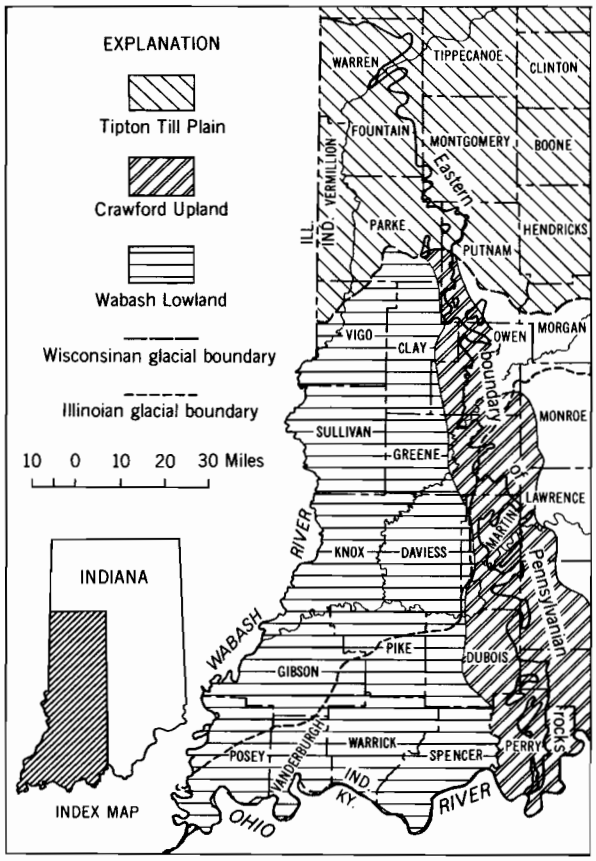

Figure 3. Map of southwestern Indiana showing physiographic units and glacial boundaries. Modified from Malott, 1922, and Wayne, 1958.

Coals are exposed in Indiana on hillsides or along streams within the hilly to rugged terrane of the physiographic units called the Wabash Lowland, Crawford Upland, and Tipton Till Plain (Malott, 1922, p. 111) (fig. 3). The Wabash Lowland includes most of the outcrop of all major commercial coalbeds in Indiana and excludes only a small portion of the Tipton Till Plain and small areas of the Crawford Upland where coals have been mined. The Wabash Lowland is an area of comparatively low relief, owing in part to the fact that the area was glaciated. The uplands are generally rolling with gentle slopes. The texture and local relief become rougher and greater as the Wabash Lowland grades eastward into the Crawford Upland and northward into the dissected edge of the Tipton Till Plain. The Crawford Upland is a rugged area with steep slopes, but few coalbeds of commercial value crop out in the region.

[1]Figure 1 has also been published at a scale of 1:380,000 as Indiana Geological Survey Miscellaneous Map 15.

Table 1. Amount of strip mine disturbed land in relation to glacial terrane

Classification of disturbed land	Terrane type areas						Total	
	Nonglaciated		Partly covered with drift of Illinoian age		Partly covered with drifts of Wisconsinan and Illinoian ages			
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Actual area of coal removed	37,350	71	34,847	75	2,293	77	74,490	
Percent		50		47		3		100
Area of additional spoil	9,033	29	11,565	25	695	23	21,293	
Percent		42		55		3		100
Total area of disturbed land	46,383	100	46,412	100	2,988	100	95,783	
Percent		48		49		3		100

The Pennsylvanian bedrock (deposited 150 to 300 million years ago) was eroded intermittently during parts of the Tertiary (1 to 60 million years ago) and Quaternary (1 million years ago to present time) Periods. This composite erosion surface was partly covered with alluvial and colluvial sediments and soil during late Tertiary time and covered with glacial drift and fluviatile sediments in several stages during the Pleistocene Epoch. The major producing coalbeds in Indiana crop out where the bedrock and the overlying unconsolidated deposits have been irregularly eroded by surface streams. The predominant surface deposits of the Wabash Lowland are till of Illinoian (Pleistocene) age and outwash sand and gravel and lacustrine silt deposits in the broad valleys. Drift of Illinoian age covers about four-fifths of the coal-producing area. Wisconsinan drift overlies Illinoian drift in the northern one-fifth of the area.

The glacial deposits have gentled the topography of the Wabash Lowland and have had an effect on strip mining. Mines in the glaciated area average less additional spoil beyond the actual mined area of coal than do the hillside contour mines in the nonglaciated part of the coal area (table 1). In the glaciated area the overburden, consisting of bedrock and drift, generally has a more level surface and a more uniform depth to coal than mines opened on steep slopes where the depth to coal increases with each cut into the hill. In addition, the unconsolidated deposits are easier to excavate than bedrock; thus where the glacial drift is thick and the bedrock thin above a coal, the expense of blasting and excavating is decreased.

The advantages of strip mining in glaciated areas are offset by several problems. The glacial materials contain some porous units that may discharge large amounts of water into the mine, generally more than is encountered in mines in the nonglaciated area. The bedrock surface is buried by the drift, and thus hidden valleys may transect the coal to reduce the actual minable reserves of the mining tract. These cutouts are in addition to any channels of Pennsylvanian age that may have eroded into the coalbeds. (See Friedman, 1960.) Glacial drift slumps readily and therefore does not have as much stability in a highwall as do sandstone and shale.

STRIP-MINED COALBEDS

The Indiana coalbeds that have been mined by stripping methods are essentially the same as those that have been deep-mined by underground methods (figs. 4 and 5). The major physical criterion used to determine the feasibility of strip mining coal is the ratio of overburden thickness to coal thickness. The maximum ratio commonly accepted is 20 to 1; that is, mining becomes uneconomical with existing equipment and mining methods when the overburden that must be moved is more than 20 times as thick as the coal. Most Indiana mines appear to operate with a ratio of about 15 to 1, and most of the earlier strip mines were close to a ratio of 10 to 1. Coalbeds that are not thick enough to be mined by underground methods can be, and have been, mined by stripping in places adjacent to the outcrop or where the overburden is thin.

The amount of each coalbed that has been strip-mined ranges from one small pit in some locally well-developed coals that are normally thin or absent to several hundred pits in the Springfield Coal Member

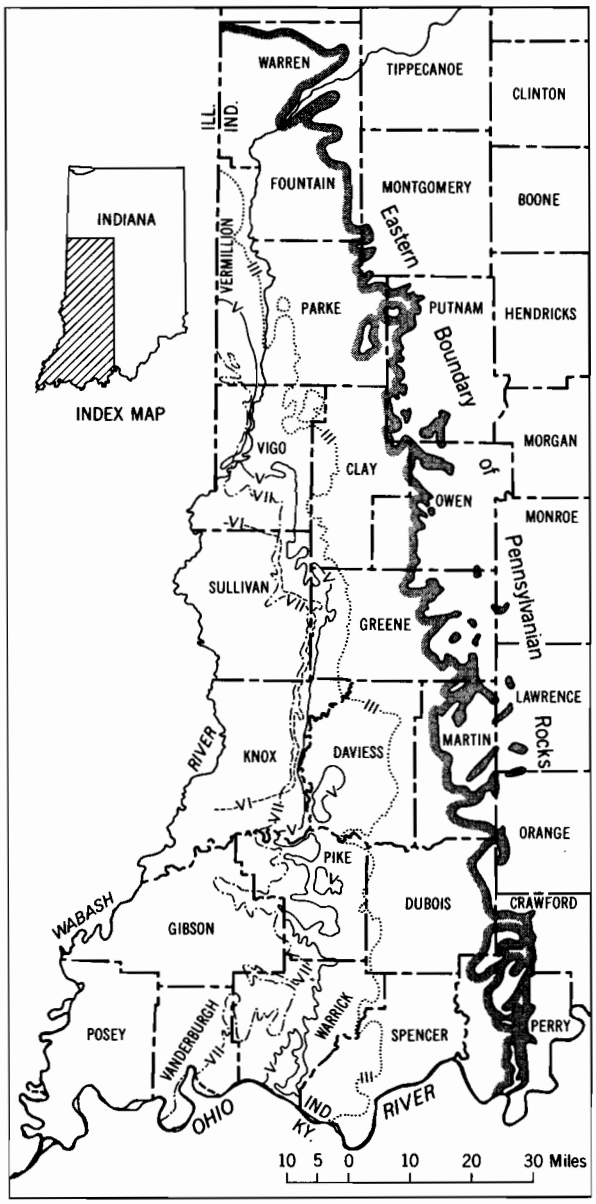

Figure 4. Map of southwestern Indiana showing the outcrop area of Pennsylvanian rocks and Seelyville (III), Springfield (V), Hymera (VI), and Danville (VII) coals. From Wier, 1957.

(V), which is universally well developed along the outcrop in Indiana. The amount of acreage mined for each coal is related directly to the quality of each coal, its availability, and its intended use. Most of the coal produced in Indiana is used for steam electric generation, but in the past it was used substantially for domestic consumption.

Strip Mining

TYPES OF STRIP MINING

Strip mining in Indiana is easily classified into two general types, provided each mine covered a large enough area to establish a pattern. Flatland, or plains type, strip mining best describes mining in the glaciated portions of the Indiana coalfield where each cut in general is straight and the overburden thickness is fairly constant (fig. 6). Contour mining aptly describes surface coal mines that follow the outcrop of the coalbed around the hillsides. In most contour strip mines the overburden thickens with each cut into the hill, mining ceases when the overburden is too thick to remove economically, and an unmined core surrounded with stripping is left (fig. 7). Spoil from hillside contour mining in Indiana seldom covers as much adjacent land or does as much damage as does the same type of mining in the Appalachian Region of eastern Kentucky, Tennessee, West Virginia, and Pennsylvania. Because of the large size of the hills and the steepness of the slopes, additional spoil in the latter area usually covers several acres for each acre mined. Spoil from the initial cut in a strip mine in flatland is commonly deposited on adjacent land that is underlain with coal, but most contour stripping around hillsides is started by throwing the overburden from the first cut down the hillside beyond the outcrop of the coal.

COAL-MINING RECOVERY

Coal mining by conventional underground methods in the past has removed from 40 to 70 percent of the coal within the mined area, depending on the roof conditions and mining methods employed. Thus from 30 to 60 percent of the coal is left unmined as pillars to support the roof (fig. 8). Some of the pillars were selectively removed (also called robbed or withdrawn) after conventional mining was finished in each area or panel. Roof collapse then progressed upward through the strata, in some places to the land surface, where a collapse sinkhole formed. Land subsidence above abandoned or collapsed mine workings has caused structural damage to buildings and highways and has otherwise disrupted normal land use.

Strip mining of coal ideally will remove all or nearly all coal from the area mined or disturbed. No pillars or blocks of unmined coal are left because of poor roof conditions as in underground mining. The disturbed area, however, nearly always exceeds the area where coal has been removed (fig. 7). The initial cut in strip mining creates a ridge of spoil on unmined land. In places this overburden is dumped on land beyond the crop of the coal, but in some operations it is deposited on land that is underlain with minable coal. The addition of the spoil to the original overburden usually makes mining the underlying coal impractical.

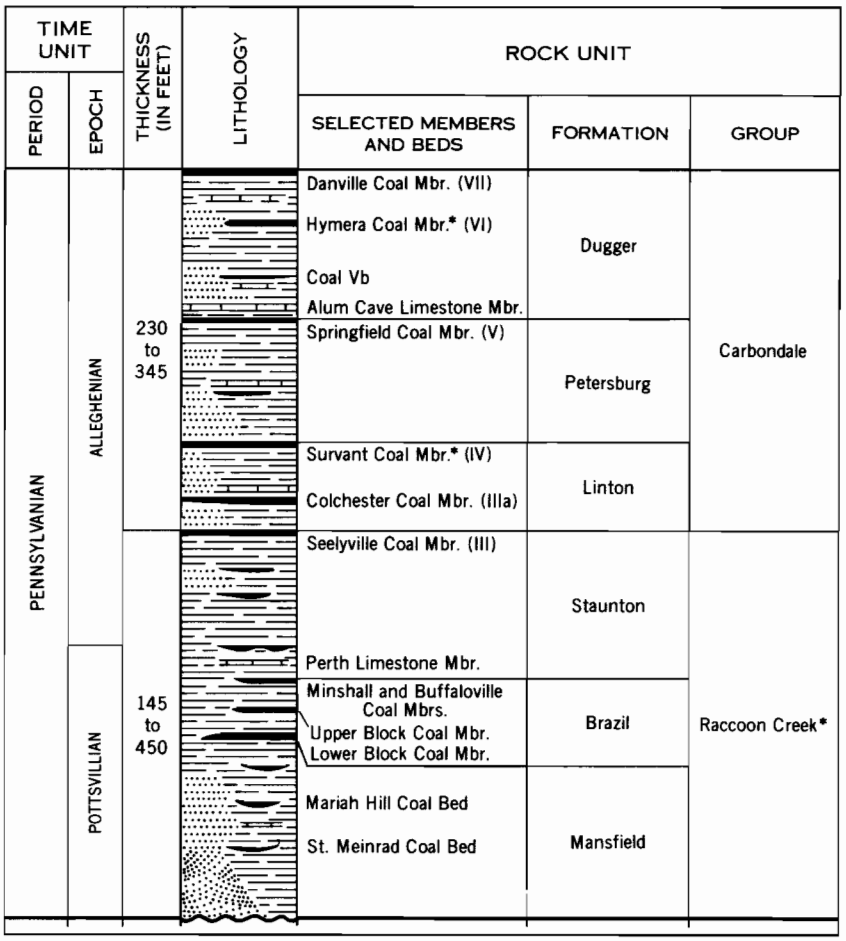

Figure 5. Generalized stratigraphic column showing the position of commercial coalbeds within the Pennsylvanian section of Indiana. Asterisk indicates names that are used here in accord with Wier's (in preparation) proposals.

STRIP-MINED LAND IN INDIANA

Approximately 100,000 acres of land has been strip-mined in 21 southwestern Indiana counties (table 2 and fig. 1). About two-thirds of the acreage is contained within three counties: Warrick, Pike, and Clay. The total disturbed area amounts to about .4 percent of the land area of the State of Indiana and less than 2 percent of the total area of the 21 counties within which the mining was done. Within Warrick and Pike Counties the strip-mined land amounts to about 10 percent of the area of each county, Clay County contains about 6 percent stripped land, and each other county has about 3 percent or less of disturbed land.

About half of the strip-mined land in Indiana is within the nonglaciated portion of the coal basin (table 1), and most of this disturbed land is within Pike and Warrick Counties (figs. 1 and 3 and table 2).

AREAS OF ACTUAL COAL REMOVAL: About 49 percent of the coal area removed by strip mining has been from the Springfield Coal Member (V) (table 3). This percentage will increase in the next few years as this coal is the one which presently is mined the most. About 23 percent of the coal area removed by strip mining has been from Hymera coal (VI) and Danville coal (VII). Pike and Warrick Counties lead in the amount of Springfield coal (V) which has been mined. The two block coals are strip-mined principally in Clay and Owen Counties, and they amount to about 11 percent of the coal-removed area in Indiana. Minable coals in the Mansfield and Staunton Formations, Minshall coal, Seelyville coal (III), and Survant coal (IV) account for about 17 percent of the total coal area removed by strip mining.

Figure 6. Map of the Chieftain Mine, Peabody Coal Co., Vigo County, showing configuration of cuts by years in flatland where the overburden is of relatively constant thickness. Note the islands left to avoid excavating cemeteries. Mine map from Maumee Collieries and Peabody Coal Co. plotted on the Lewis and Pimento Quadrangles, U.S. Geological Survey, 1963 and 1958.

ADDITIONAL DISTURBED AREAS: Nearly all strip mines disturb the land adjacent to the open cuts to some degree, especially in the excavation of the initial cut. The average amount of disturbed area in addition to the area where the coal has been removed is about 22 percent of the total disturbed area in all the strip-

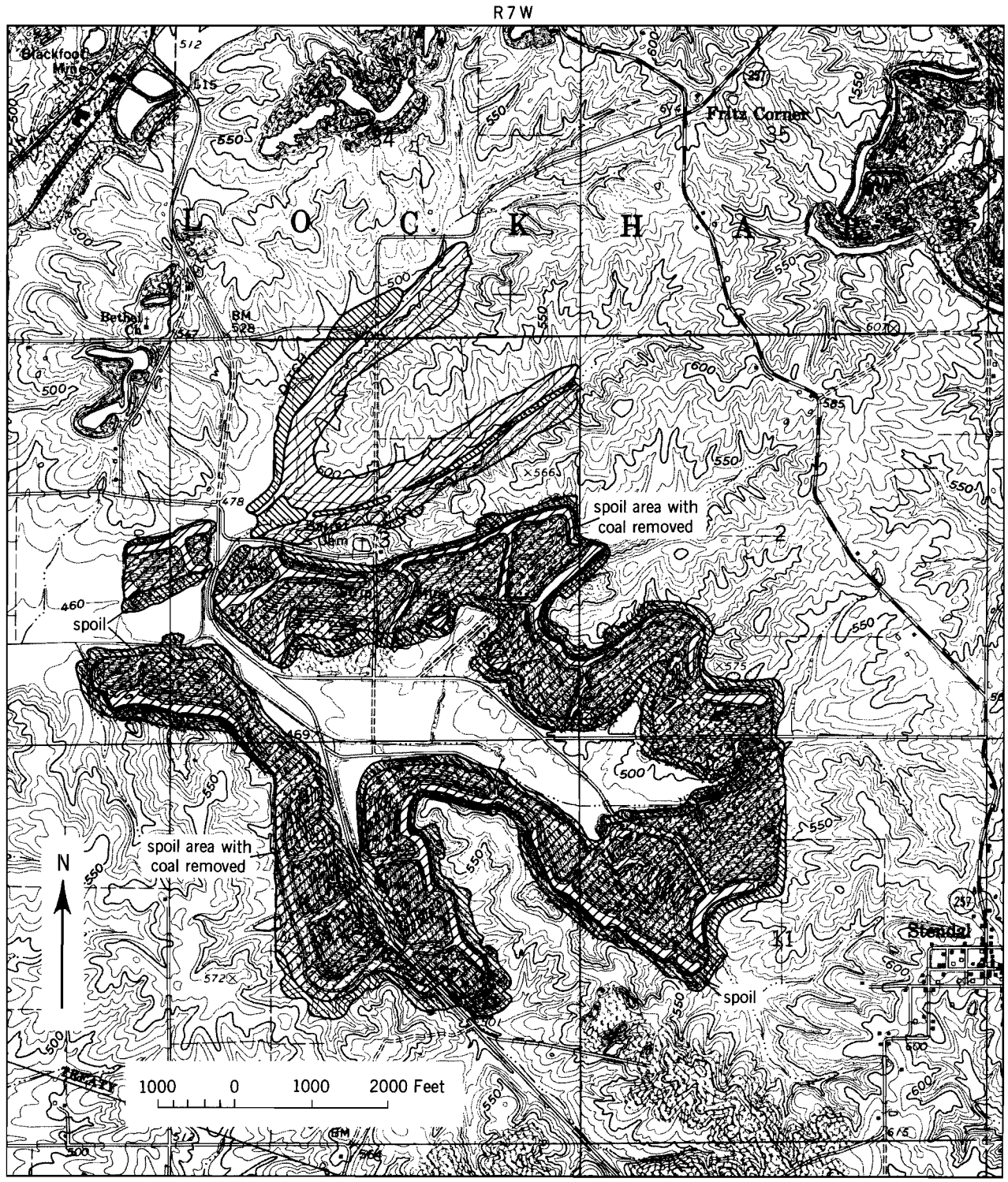

Figure 7. Map of the Houchin Creek Mine, Blackfoot Coal Co., Pike County, showing contour stripping around hillsides. Mine map from Blackfoot Coal Co. and aerial photographs and topographic base from the Augusta Quadrangle, U.S. Geological Survey, 1961.

mined counties. The average of some of the largest strip mines, those that exceed 1 square mile in area, is about 17 percent. Tipple areas, sludge ponds, and refuse piles have not been included as part of the

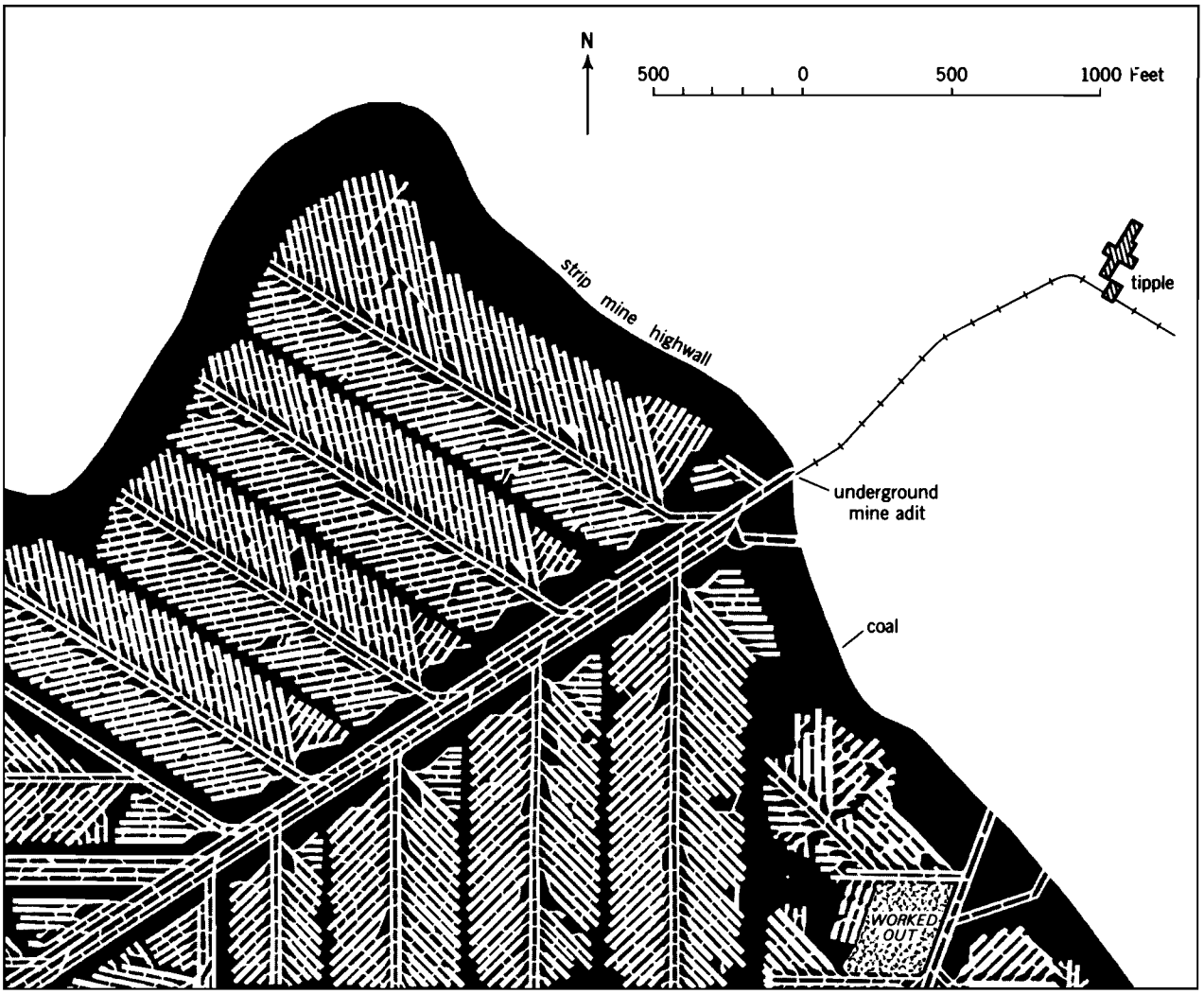

Figure 8. Map of a mined area showing where coal has been removed by strip mining and partly removed by deep mining. The underground mine adit is in the strip mine highwall. Coal recovery by the underground mine is about 50 percent. Mine map of the Minnehaha Mine, Sullivan County.

additional spoil. In general, the smaller the strip-mined area, the higher the percentage of additional spoil to the total disturbed area. Many operators of small strip mines have dumped spoil on an unmined area larger than the area from which they have removed the coal. As a result, the additional spoil accounts for more than 50 percent of the total disturbed area of the mine.

Mines in the nonglaciated area average about 30 percent additional spoil because many of them are of the hillside contour type. Mines in the glaciated parts of the coal basin average about 25 percent additional spoil because much of the mining is of the flatland type. Nearly all mining in Vigo and Vermillion Counties and much of it in Clay, Greene, Sullivan, Knox, and Daviess Counties is in drift-covered areas and is of the flatland type. In general, these counties average about 20 to 30 percent additional spoil compared with about 40 percent in Spencer County, where mining is mostly of the hillside contour type (table 2). Two counties have unique amounts of additional spoil: In Clay County additional spoil averages about 30 percent primarily because of the large number of small strip mines, and in Gibson County additional spoil averages about 14 percent within the nonglaciated area because the mining is on gently rolling topography.

Factors other than terrane influence the amount of additional spoil at any strip mine. These factors range from those related to engineering practices, such as surface-water control and planning for future land use, to economic reasons based on mining costs

Table 2. Strip-mined land in Indiana[1]

County	Total area of county (thousands of acres)	Total disturbed area in county		Actual area of coal removed		Area of additional spoil	
		(acres)	(pct)	(acres)	(pct)	(acres)	(pct)
Clay	232.9	14,177	5.8	10,109	71	4,068	29
Crawford	199.7	2*	---	2*	---	-------	---
Daviess	277.1	1,319	0.5	895	68	424	32
Dubois	276.8	148*	---	78*	53	70*	47
Fountain	254.1	477	0.2	367	77	110	23
Gibson	319.3	737	0.2	632	86	105	14
Greene	351.3	9.949	2.8	7,935	80	2,014	20
Knox	330.9	2,205	0.7	1,813	82	392	18
Martin	220.8	92	---	66	71	26	29
Monroe	262.2	2*	---	2*	---	-------	---
Owen	246.4	2,033	0.8	1,341	66	692	34
Parke	288.6	539	0.2	381	71	158	29
Perry	245.8	32	---	14	44	18	56
Pike	214.4	20,861	9.7	16,818	81	4,043	19
Putnam	312.3	23	---	16	70	7	30
Spencer	253.4	1,623	0.6	954	59	669	41
Sullivan	292.5	9,091	3.1	6,629	73	2,462	27
Vermillion	168.3	2,198	1.3	1,755	80	443	20
Vigo	265.6	7,243	2.7	5,806	80	1,437	20
Warren	235.5	40*	---	20*	50	20*	50
Warrick	250.2	22,992	9.2	18,857	82	4,135	18
Total	5,498.1	95,783	---	74,490	78	21,293	22
Percentage for all 21 counties			1.7				

[1]Areal distribution only; multiple stripping not calculated. Data to June 1967.
*Estimated.

and the skill (or lack thereof) of the stripping machine operator.

HISTORY OF STRIP MINING IN INDIANA

Strip mining was probably the first type of coal mining in Indiana because surface exposures of coalbeds could be easily removed after scraping off a few feet of loose overburden. In the early 1800's mining was done with a pick and a shovel at a small pit or with a horse-drawn scraper at a larger operation (Wier, 1959). These early strip mines were very small by modern standards, and as many of them cannot be seen today, they are not included in this study. Most of the coal produced in Indiana during the late 1800's and early 1900's was from underground mines and was primarily for domestic use.

Coal production from strip mines increased steadily from the end of World War I to World War II, and strip mining has generally accounted for more than half of the coal produced since 1940 (fig. 9). Mining methods and equipment have improved continuously in the half century since World War I. At present strip mine production exceeds deep mine production by five times and should continue to do so until new modern deep mines are opened.

After World War I strip mining was done with steam and electric-powered shovels that moved on

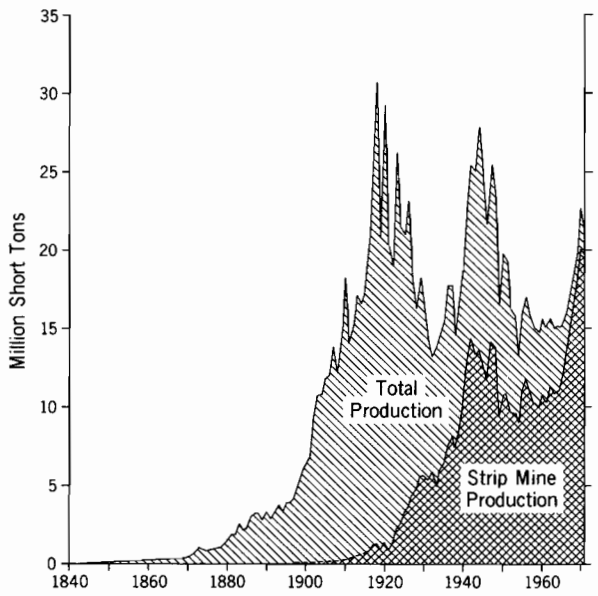

Figure 9. Graph showing the comparison of strip mine production to all coal production in Indiana. Data from U.S. Bureau of Mines and Indiana Coal Association.

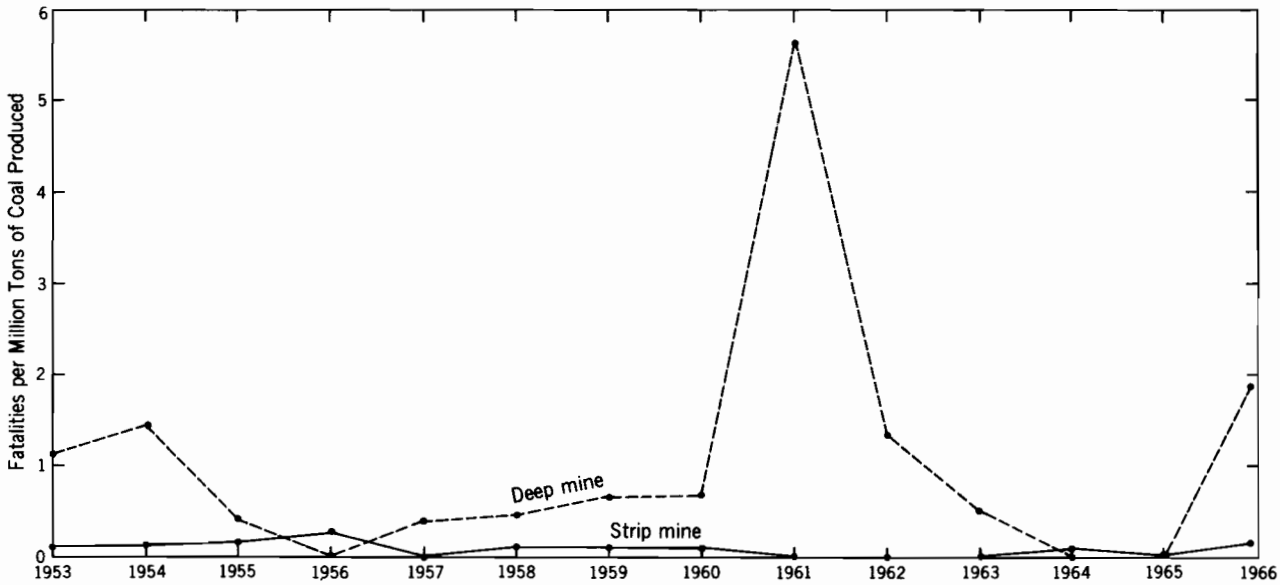

Figure 10. Graph showing the comparison of fatalities in underground mines and strip mines, excluding non-mine surface accidents, 1953-66. The large number of underground mine deaths in 1961 was mostly the result of the Viking Mine explosion in Vigo County. Data from Information Circulars of the U.S. Bureau of Mines for the years indicated.

rails. The bucket capacity ranged from 3 to 6 cubic yards, and the machines could generally mine to a depth of 40 feet. By the late 1920's most new stripping machines were constructed on crawlers to provide greater mobility than rails do. Draglines capable of mining deeper than 40 feet also came into use during this period. During the 1930's and 1940's bucket sizes on shovels increased from a capacity of 20 yards to 30 yards, and draglines were as much as 12 yards.

Mammoth shovels began to appear in the strip mines in the late 1950's. Dipper capacity on shovels exceeded 50 yards, and buckets on draglines were nearly as large. But these machines would seem small compared with present-day gigantic shovels with bucket sizes of 100 to 200 yards.

The size and cost of stripping equipment are approaching the point where smaller equipment for deep mining may prove more efficient. The use of longwall-mining machinery for underground mining is increasing rapidly. New equipment has the advantage of removing nearly all the coal in a continuous sweep or advance underground. The wasteful system of leaving pillars as was formerly done in deep mines is surmounted by caving the mine roof immediately adjacent to the working face. Underground-mining systems that are electronically and computer controlled to reduce manpower are being developed. One distinct advantage of efficient underground mining is that the operation is sheltered from weather conditions which affect surface mining.

The number of deep-mining fatalities in relation to the mine tonnage produced has always been high, but this number has been increasing. Strip mining has generally been safer, primarily because the working space is more open and better lighted (fig. 10). The major dangers of falling rock, gas and dust explosion, and working in cramped quarters with machinery are eliminated or reduced in strip mines.

CURRENT AND FUTURE STRIP MINE PRODUCTION

Data from the Mid-West Coal Producers Institute, Inc. (1964-66) pertaining to the five major strip-mining counties, combined with an estimate for all remaining counties, indicate that about 2,925 acres were strip-mined for coal in Indiana in 1966 and about 15 million tons of coal was produced. Coal mining by open-pit methods has increased and underground mining decreased to the point that strip mine production now exceeds underground mine production by several times. Production from the two methods of mining should maintain its present relationship for several years, until new deep mines that utilize modern underground-mining techniques are opened in Indiana.

Indiana has about 33 billion tons of coal reserves, and 17 billion tons are recoverable by present deep- and strip-mining techniques. If the limit of overbur-

Table 3. Acreage of strip-mined coal and
[Data taken in part from Indiana Geological

County	Coal							
	Mansfield Fm.[2]		Upper and Lower Block		Minshall and Buffaloville		Staunton Fm.	
	Strip-mined	Spoil area	Strip-mined	Spoil area	Strip-mined	Spoil area	Strip-mined	Spoil area
Clay	-------	-------	6,099	2,871	456	62	60	45
Crawford	2*	-------	-------	-------	-------	-------	-------	-------
Daviess	164	95	-------	-------	-------	-------	731	329
Dubois	25*	20*	3*	2*	35*	30*	15*	18*
Fountain	-------	-------	-------	-------	-------	-------	367	110
Gibson	-------	-------	-------	-------	-------	-------	-------	-------
Greene	-------	-------	245	186	48	36	186	82
Knox	-------	-------	-------	-------	-------	-------	-------	-------
Martin	66	26	-------	-------	-------	-------	-------	-------
Monroe	2*	-------	-------	-------	-------	-------	-------	-------
Owen	-------	-------	1,341	692	-------	-------	-------	-------
Parke	-------	-------	314	134	32*	1	35	23
Perry	14	18	-------	-------	-------	-------	-------	-------
Pike	-------	-------	-------	-------	-------	-------	-------	-------
Putnam	16	7	-------	-------	-------	-------	-------	-------
Spencer	390	270	30	18	532	381	1	-------
Sullivan	-------	-------	-------	-------	-------	-------	-------	-------
Vermillion	-------	-------	-------	-------	-------	-------	-------	-------
Vigo	-------	-------	-------	-------	-------	-------	-------	-------
Warren	-------	-------	-------	-------	10*	10*	10*	10*
Warrick	-------	-------	-------	-------	-------	-------	-------	-------
Total	679	436	8,032	3,903	1,113	520	1,405	617
Percentage of total	.91	-------	10.78	-------	1.49	-------	1.89	-------
Total disturbed area	----- 1,115 -----		----- 11,935 -----		----- 1,633 -----		----- 2,022 -----	
Percentage of additional spoil area of total disturbed area	---------- 39.1 ----		---------- 32.7 ----		---------- 31.8 ----		---------- 30.5 ----	

[1]Removal of all mined coal from strip-mined areas, including double stripping and restripping.

[2]Primarily produced from the Mariah Hill and St. Meinrad coals.

[3]Includes small areas of a thin rider coal.

[4]Some operations in Pike and Warrick Counties produce both coals VI and VII, locally called Millersburg coals, from the same area; these areas are here included with the Hymera coal (VI) only.

*Estimated.

den thickness is 90 feet, about 2.2 billion tons of coal is strippable (Indiana Geological Survey, 1965). Mines in which more than 90 feet of overburden is removed are now in operation, but they are not common in Indiana. About 2.2 billion tons of coal has been mined in Indiana by all types of mining since the area was first settled. Of this amount about 770 million tons has been removed by strip mining since about 1918. If the present strippable reserves were strip-mined at the present rate, they would last for about 150 years. But because strip mine production has increased an average of about 10 percent per year for the past several years, strippable reserves with less than 90 feet of overburden will last considerably less than 150 years. On the other hand, vast reserves exist beneath 90 to 120 feet of overburden (Spencer, 1953, p. 19).

STRIP-MINED LAND RECLAMATION

Strip mining for coal completely transforms the overburden from an original layered sequence of bedrock strata (shale, sandstone, limestone, and thin coalbeds) and various soil zones to a heterogeneous mixture of rock fragments and dirt. Various reclamation methods have been used to minimize the effects of strip mining and to restore the land to productivity.

Strip mine operators in Indiana pioneered stripped-land reclamation in the United States when some of

additional spoil areas in Indiana[1]
Survey Preliminary Coal Maps 1-13]

Coal										Total	
Seelyville[3] (III)		Survant[3] (IV)		Springfield[3] (V)		Hymera[4] (VI)		Danville[4] (VII)			
Strip-mined	Spoil area	Strip-mined	Spoil area	Strip-mined	Spoil area	Strip-mined	Spoil area	Strip-mined	Spoil area	Strip-mined	Spoil area
2,599	761	691	323	102	6	102	-------	-------	-------	10,109	4,068
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	2*	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	895	424
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	78*	70*
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	367	110
-------	-------	-------	-------	295	41	102	7	235	57	632	105
132	25	3,979	736	1,939	541	1,326	408	80	0	7,935	2,014
-------	-------	-------	-------	220	74	1,576	318	17	0	1,813	392
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	66	26
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	2*	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	1,341	692
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	381	158
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	14	18
-------	-------	946	388	15,387	3,462	485	193	-------	-------	16,818	4,043
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	16	7
1	-------	-------	-------	-------	-------	-------	-------	-------	-------	954	669
-------	-------	-------	-------	1,313	363	2,549	941	2,767	1,158	6,629	2,462
32	31	-------	-------	329	82	-------	-------	1,394	330	1,755	443
354	300	858	127	3,331	661	-------	-------	1,263	349	5,806	1,437
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	20*	20*
-------	-------	-------	-------	13,339	3,079	5,518	1,056	-------	-------	18,857	4,135
3,118	1,117	6,474	1,574	36,255	8,309	11,658	2,923	5,756	1,894	74,490	21,293
4.19	-------	8.69	-------	48.67	-------	15.65	-------	7.73	-------	100.00	-------
----- 4,235-----		----- 8,048-----		----44,564-----		-----14,581-----		----- 7,650-----		-----95,783-----	
----------26.4---		----------19.6---		----------18.7---		----------20.0---		----------24.8---		----------22.2---	

the early miners banded together as the Indiana Coal Producers Association in 1918 and decided to revegetate part of the spoil banks they had created. Their prime interest was reforestation, either to obtain a cash crop or to hide the spoil banks. Most early plantings, starting about 1926, were of locust for posts, but they did include some hardwoods and pines, which were of greater commercial value. All plantings were experimental, for much was to be learned about growing trees on rugged land with harsh acidic soil and rock.

The concept of reforestation, still somewhat experimental, for trees do not grow significantly in less than a decade, should not be confused with land restoration. Restoration means reworking the spoil banks, at some expense to economically minded coal operators, to reshape the land either to its original contour or to some other topography suitable for commercial use.

In the past some strip mine operators have abandoned their mined-out coal workings without any attempt at reclamation or reforestation. Most of these abandoned holdings, known within the mining trade as "orphan banks," were those of small operators. Not all early mine operators joined the Indiana Coal Producers Association. As a result, the State of Indiana enacted the second strip mine legislation in the nation in 1941, when the state required all companies to

make reclamation and reforestation efforts and required them to secure bonds and permits to insure their compliance. The law, formulated with the cooperation of the Indiana Coal Producers Association, included a provision for revegetating abandoned land by requiring each active company to reforest 1 percent more stripped land than it mined each year. A later amendment required that the crowns of spoil banks adjacent to public roads be graded and that access roads be provided.

The problem of reforesting highly acid mined land was recognized and partly surmounted by allowing the coal companies to plant substitute land. This policy enabled the companies to let their land settle and the acid leach out naturally for a few years before they attempted to plant it. At the same time the coal operators planted some mined lands that had been abandoned by earlier operators. As a result of this policy, nearly all land in Indiana strip-mined prior to about 1963 has been reforested or reclaimed according to law. This does not mean that all spoil banks are covered with forests, for some plantings were nearly complete failures and others did not do very well, but in general some type of vegetation was planted. In some mined areas natural vegetation has covered the area, but natural revegetation is uneven in distribution, is variable in size, and includes many noncommercial plant species.

The problem of plant survival on different slopes is directly related to the soil acidity and texture (silty, clayey, sandy, or rocky). At the same time, soil erosion and internal drainage are determined by soil texture and the amount of vegetal cover needed to hold surface water in place. Leaching of acids from porous spoil may be rapid because of easy infiltration of surface water, but leaching from silty and clayey soils may be slow because of rapid surface-water runoff and lack of infiltration on steep slopes. Grading of clayey ridges may well compact the soils and prevent water infiltration, but grading on sandy and rocky spoil would not be as harmful. Forestry experts have long claimed that grading the tops of the spoil ridges will compact the ground and diminish healthy tree growth, yet many species will not grow well on the crowns anyway because they are too well drained.

The coal operators have also restored strip-mined land successfully in some places, for they have generally applied their efforts in the most feasible places. In some places the land was restored essentially to the original contour, either as a coal company project or as an agreement with the landowner of the leased land. Most of the restored land is not now identifiable as former strip mines, although its soil and vegetation may not be comparable to adjacent land. Recontouring spoil banks does not appreciably affect the acidity of the soil; in fact, grading to smooth slopes may produce faster water runoff and less infiltration and thus slow down the leaching process that removes the acids. Most of the recontoured land has been reclaimed for pasture or agricultural use; some has been used for homesites.

Meadowlark Farm, strip-mined land northeast of Terre Haute operated by Ayrshire Coal Co. at their Chinook Mine in Clay County, is an excellent example of productive reclamation of strip-mined land. Much of the land was graded to low and rolling topography and planted as pasture for a cattle herd. Only a few long lakes are reminders of the former strip mine in the reclaimed area. Ayrshire has another strip mine farm near Clinton in Vermillion County (Mined-Land Conservation Conference, 1966).

Several mining sites have been donated, leased, or sold to the State of Indiana for the development of recreation facilities (fig. 11). Scales Lake State Beach, near Boonville in Warrick County, was given to the state in December 1933. This 477-acre tract consists of a 60-acre lake impounded in the valley between two hillsides that were strip-mined. The land was part of the state forest from 1935 until about 1952, and a small fish hatchery has been operated there for many years.

The Central Indiana Coal Co., now defunct, donated 1,358 acres in Greene and Sullivan Counties to the State of Indiana in 1935. About 50 percent of the land area, now called the Greene-Sullivan State Forest, had been strip-mined for coal. (A 5-acre tract including a house was purchased in 1943 for $1,817.28. The Central Indiana Coal Co. and Maumee Collieries donated an additional 2,028.86 acres to the Greene-Sullivan State Forest in 1949.) Peabody Coal Co., successor to Maumee Collieries, has made several agreements with the State of Indiana for trading mined land for unmined state-owned land. As a result of the exchanges, the Greene-Sullivan State Forest now contains about 5,488 acres (fig. 12). Much of this land has been strip-mined and contains numerous small ponds and lakes; some of it has been opened for public picnicking, camping, hiking, and fishing.

Three coal companies have leased mined and nonmined land to the State of Indiana in Pike and Gibson Counties along the Patoka River. The Patoka State Fish and Game Area contains many strip mine lakes open for public recreation.

The use of strip-mined land for public recreation is not limited to state management. Several private sites have been improved and opened to the public

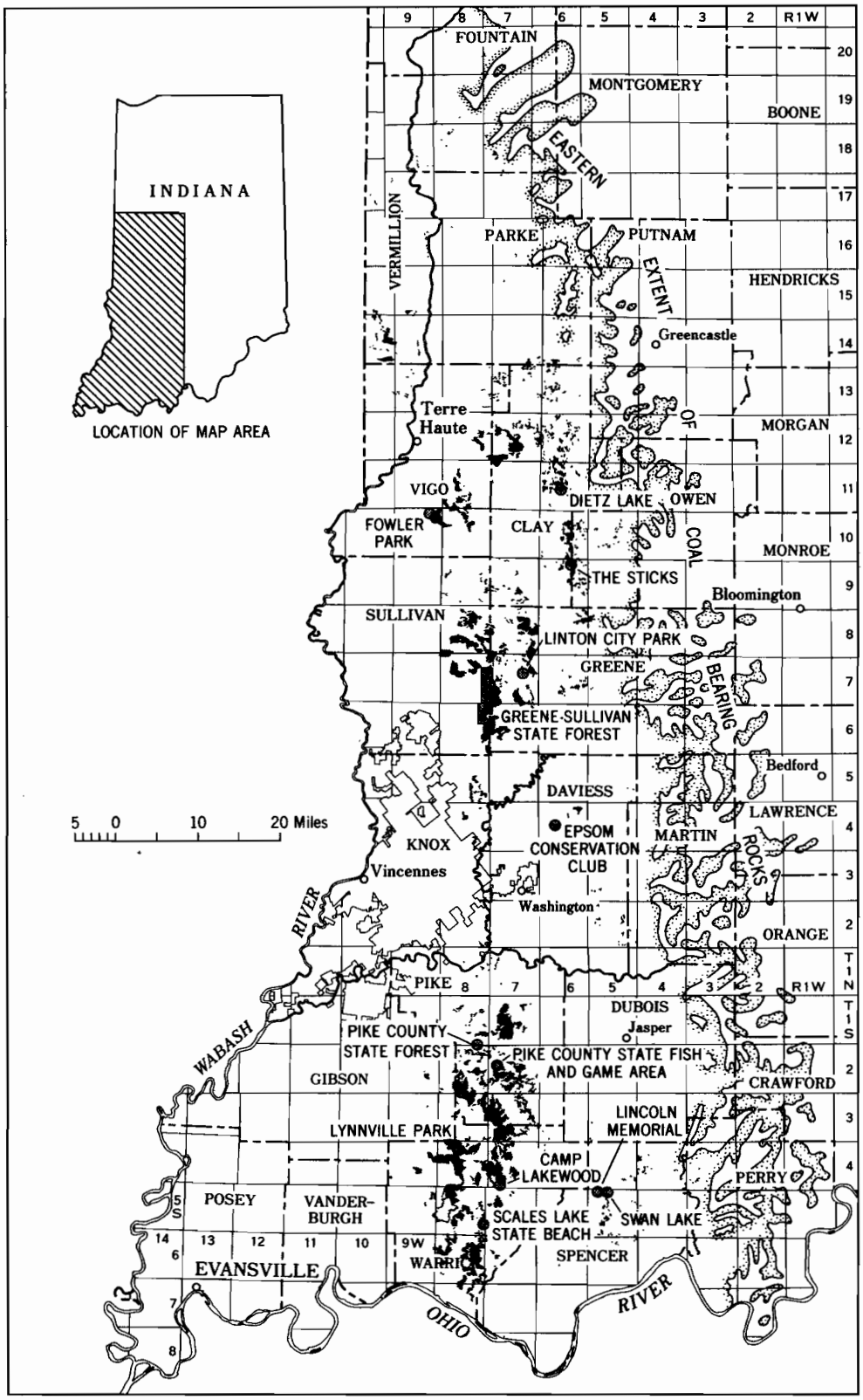

Figure 11. Map of southwestern Indiana showing the location of recreation areas at strip mine sites.

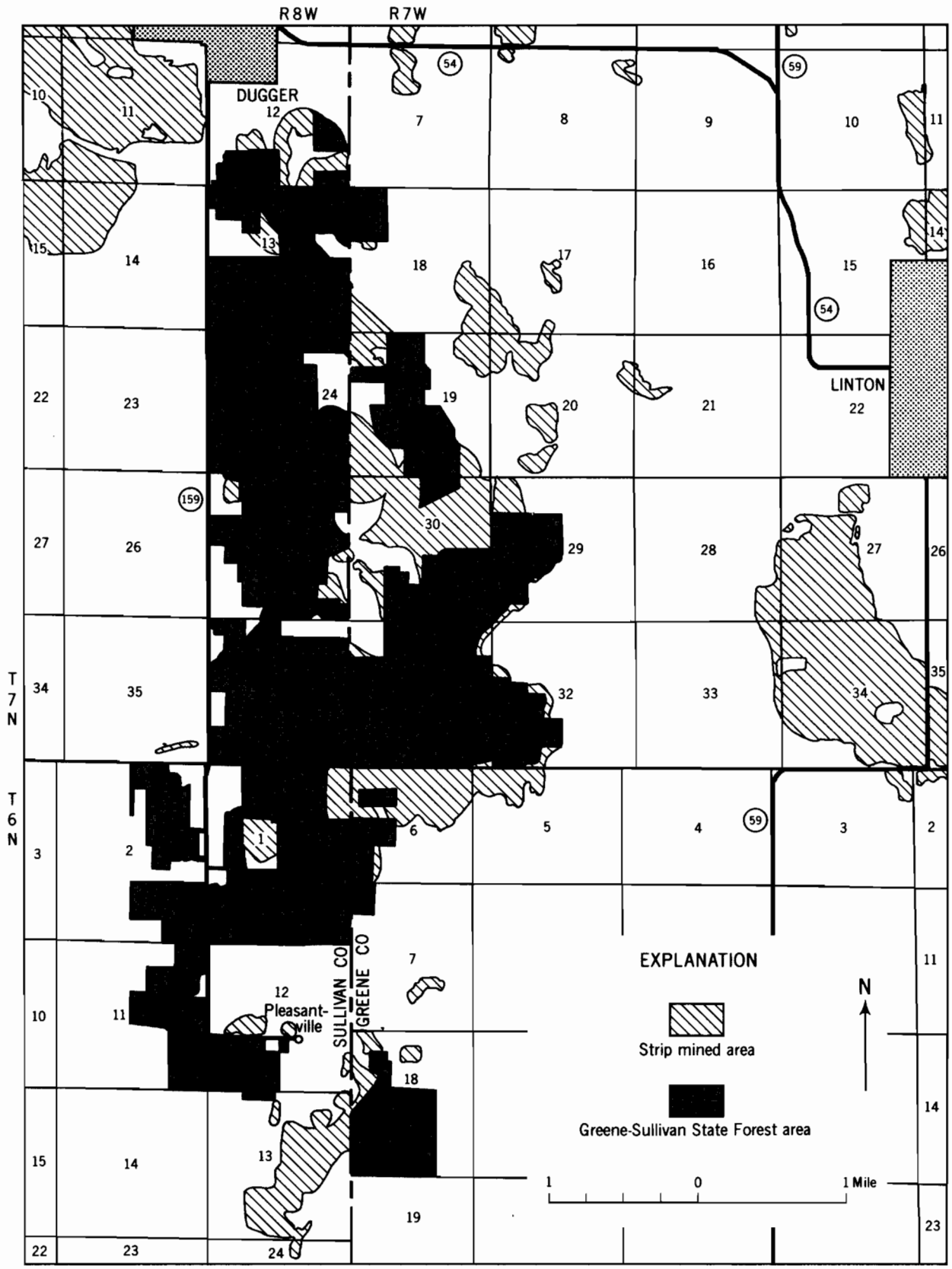

Figure 12. Map showing distribution of strip mines in the Greene-Sullivan State Forest.

with considerable success. Dietz Lake in Clay County consists of about 360 acres, most of which is strip-mined land, and includes fishing, swimming, camping, picnicking, and cabin facilities. Another area in Clay County, called "The Sticks," is similar, but smaller. Swan Lake, just east of the Lincoln Memorial in Spencer County, was operated as a fishing area for several years.

Considerable benefit to water resources or damage to local streams may result from strip mining. There is a great increase of groundwater absorption in an area that has been strip-mined, and thus surface-water runoff is reduced. Some of this water is evident within the strip mine lakes and ponds, but much of it infiltrates into the spoil or cast overburden and then slowly discharges back into surface drainage and bedrock aquifers. A recent study has indicated the effect that strip mine spoil has on runoff retention and slow release to surface streams to maintain low flows during droughty summer months (Corbett, 1965).

Drainage from strip-mined areas, however, may present a problem in stream pollution. Highly acid water may be present in the spoil or in runoff from the spoil for several years before the deleterious elements are leached out or neutralized, and thus copperas-laden water may be produced locally in the streams. Most of this pollution is derived from unsealed underground mines and refuse piles at coal preparation plants. The effect of acid water within the lake or pond in the last cut of the strip mine is minimized by covering the coal with a blanket of spoil or earth.

Fishing for recreation is no doubt the greatest use of strip mine ponds and lakes, but their use as domestic, agricultural, stock, and industrial water supplies is important. The water supply for Lynnville comes from a small lake (about 190 acres) that is on a 1,100-acre tract donated to the town by the Peabody Coal Co. The lake also serves as a recreation site. Several coal preparation plants obtain water from lakes, some of which are strip mine lakes of their own creation.

The use of strip-mined land for homesites, especially acreage that fronts on lakes and ponds, is increasing. The value of stripped land for homesites near cities and towns far exceeds the original value of the land for agricultural use and may approach the value per acre of the coal mined. In some areas the land value for homesites may even exceed the profit derived from coal mining.

The Indiana Legislature enacted a new reclamation law in 1967, effective in 1968, which requires more grading of spoil banks than has been done previously. Grading standards were established for three major types of land use: (1) forest or range, (2) pasture and hay, and (3) row crop (tillable land). The maximum slope that is allowable now is 33.3 percent, which is acceptable only for forestland or rangeland. Land that is to be used as rangeland must have a pH of 5.5 or higher. Land that is to be reclaimed for pasture and hay must be graded to slopes less than 25 percent, and rocks larger than 6 inches in diameter that will not disintegrate in 3 years must be covered with 6 inches of soil. Land to be restored as tillable land must have a slope of 8 percent or less, and large rocks which will not disintegrate must be buried under 18 inches of soil. In all types of land use the outside slope on the box cut must be graded to a slope within 33.3 percent of adjacent undisturbed land.

Compliance with the new law will do much to reduce the sharp profile and elevations of the spoil banks and thus to gentle the general ruggedness of the topography. But problems concerned with meeting the new slope requirements still remain. Dumping the spoil in a new pattern during mining may provide better spoil distribution but may not be practical because of increased operating costs.

Conclusions

Land in Indiana that has been strip-mined for coal amounts to a small part of the total land area of the state and, in fact, to a very small part of the land in most of the counties within which the mining was done. Only three counties, Warrick, Pike, and Clay, have lost a significant part of productive land. Information in this report should be useful to those directly concerned with conserving, developing, reclaiming, reforesting, and regulating strip-mined land in Indiana.

At least four facts support strip mining for coal. First, nearly all strip-mined coal is recovered; little coal is left in the ground as unrecoverable. Second, the fatality rate among strip mine workers is significantly lower than it is among underground mine workers. Third, the output of strip mine workers is much higher than the output of underground mine workers. Fourth, a mining company can reclaim most of the strip-mined land by giving proper consideration to the physical and chemical properties of the many kinds of rock in the overburden.

Literature Cited

Corbett, D. M.

1965 - Water supplied by coal surface mines, Pike County, Indiana: Indiana Univ. Water Resources Research Center Rept. Inv. 1, 67 p., 1 pl., 2 figs., 15 tables.

Friedman, S. A.
1960 - Channel-fill sandstones in the middle Pennsylvanian rocks of Indiana: Indiana Geol. Survey Rept. Prog. 23, 59 p., 2 pls., 16 figs., 1 table.
Indiana Geological Survey
1965 - Preliminary coal reserves study as of 1965: open-file report.
Malott, C. A.
1922 - The physiography of Indiana, *in* Handbook of Indiana geology: Indiana Dept. Conserv. Pub. 21, pt. 2, p. 59-256, 3 pls., 51 figs., 1 table.
Mid-West Coal Producers Institute, Inc.
1964-66 - Summary tables of mining and reclamation data by counties: internal report.
Mined-Land Conservation Conference
1966 - Ayrshire Meadowlark Farms enter third decade showing profit: v. 2, no. 4.
Powell, R. L.
1972 - Map of southwestern Indiana showing areas strip mined for coal, revised: Indiana Geol. Survey Misc. Map 15.
Spencer, F. D.
1953 - Coal resources of Indiana: U.S. Geol. Survey Circ. 266, 42 p., 16 figs., 11 tables.
Trumbull, James
1960 - Coal fields of the United States, Sheet 1: U.S. Geol. Survey.
Wayne, W. J.
1958 - Glacial geology of Indiana: Indiana Geol. Survey Atlas Mineral Resources Map 10.
Wier, C. E.
1957 - Directory of coal producers in Indiana: Indiana Geol. Survey Directory 5, 100 p., 1 pl., 3 figs., 1 table.
1959 - Coal mining in Indiana, 1812-1958: Outdoor Indiana, v. 2, no. 9, p. 11-15.
19__ - Stratigraphy of the middle and upper Pennsylvanian rocks in southwestern Indiana: Indiana Geol. Survey Bull. ___ [in preparation].